

Challenges and limitations of introducing pigeonpea as a new crop into smallholder farming systems through farmer-to-farmer education in Zambia

Hamid Khazaei¹  | Sebastian Scott²  | Jarkko K. Niemi¹ 

¹Natural Resources Institute Finland (Luke), Helsinki, Finland

²Grassroots Trust Limited (GrT), Lusaka, Zambia

Correspondence

Hamid Khazaei, Natural Resources Institute Finland (Luke), Helsinki, Finland.
Email: hamid.khazaei@luke.fi

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Societal Impact Statement

Legume plants offer generous benefits for both the planet and people by supporting sustainable farming, food and feed systems through their ability to symbiotically fix atmospheric nitrogen. While grain legumes are cultivated and consumed globally, their adoption, market development, and integration into cropping systems vary. In Zambia, pigeonpea remains an underutilised legume crop despite its suitability for semiarid conditions and potential to diversify food and income sources. We implemented farmer field schools in the Eastern province of Zambia to introduce pigeonpea, strengthen farmer knowledge, and explore how participatory learning can support its adoption and early-stage value chain development.

Summary

- Farmer field schools (FFSs) are transformative, participatory approaches to adult agricultural education that effectively promote farmers' learning and capacity building and empower farming communities with practical knowledge. Here, we present a case study of FFSs in the Katete district, Eastern province of Zambia, focused on good pigeonpea agronomic practices and the value chain.
- Three FFSs were established, focusing on pigeonpea variety trials, biological pesticides, and a pigeonpea-specific rhizobial inoculant development and testing. Farmers received hands-on training and resources and were guided through community-led trials.
- Extreme weather conditions, free-grazing livestock, an underdeveloped pigeonpea seed value chain, and a poor seed system hindered the implementation of the FFSs. Despite the challenges encountered, we successfully designed and tested pigeonpea-specific rhizobial inoculants, trained farmers in good agronomic practices such as biological pest control, and provided access to seed of improved pigeonpea varieties. To strengthen the pigeonpea seed value chain, a seed dehuller is now available to farmers.

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- Pigeonpea FFSs will support crop and food diversification, improve soil fertility and sustainable agriculture, and may increase household income.

KEYWORDS

Africa, farmer education, grain legumes, rhizobial inoculation, seed processing

1 | INTRODUCTION

Farmer field schools (FFSs) are participatory, peer-to-peer learning initiatives where smallholder farmers establish and manage demonstration plots to test and showcase agricultural technologies that enhance resilience, productivity, profitability, and household nutrition security. Using experiential and group-based methods, FFSs support farmer decision-making, problem-solving, and the adoption of new practices (Davis et al., 2012; FAO, 2001). Given their positive impact on rural livelihoods, they have substantial potential to contribute to the United Nations Sustainable Development Goals (van den Berg et al., 2020). FFSs have been implemented and adapted globally including Africa (e.g., Asiabaka, 2002; Duveskog et al., 2011; Pienaaah et al., 2024; van den Berg et al., 2021 & 2021). In Zambia, FFSs were established through FAO-supported initiatives (Anandajayasekeram et al., 2007; Braun et al., 2006) and have since expanded under both government and NGO programmes with diverse focus areas and methodologies (Ministry of Agriculture Zambia, 2018; SelfHelp Africa, 2014; World Bank, 2019; World Vision, 2021).

FFSs can help smallholders adopt and market new crops such as pigeonpea (*Cajanus cajan*) in Zambia. Other participatory approaches such as on-farm trials, participatory variety selection, and farmer-managed experimentation have also been used successfully to promote crop diversification, improve nutrition, enhance soil fertility, and increase the adoption of pigeonpea in Eastern and Southern Africa (Kerr et al., 2007; Simtowe et al., 2016; Snapp et al., 2019). Compared with these approaches, FFSs place greater emphasis on collective learning, peer-to-peer exchange, and iterative decision-making over the course of a season, which can be particularly important when farmers are evaluating the risks and opportunities associated with introducing a new crop. Conventional FFS models are resource-intensive and time-demanding, so low-intensity adaptations that retain core social-learning benefits are advisable (Simtowe & Muange, 2013).

Pigeonpea is a climate-resilient legume for Eastern Zambia with potential for food, feed, income, and agroforestry. In the semiarid tropics, particularly during the dry season, the deep-rooted pigeonpea crop serves as insurance against drought (Sameer Kumar et al., 2017) while nurturing the soil for other crops as a great symbiotic nitrogen-fixer grain legume crop (Namatsheve et al., 2025; Peoples et al., 2021). Its seeds are rich in protein (21–28% seed dry weight) along with vital amino acids and vitamins (Gomezulu & Mongi, 2022). It is traditionally consumed in small quantities in Zambia as a fresh vegetable or as a whole dry grain. Cooking whole dry grains requires substantial cooking time and is less favourable compared with alternative grain legumes

such as cowpea (*Vigna unguiculata*) and common bean (*Phaseolus vulgaris*). In India, the main producer and consumer of pigeonpea, its dry, split, and dehulled seeds (dahl) are used as food (Locali-Pereira et al., 2023). Increasing local and global demand for this crop presents an opportunity to boost productivity, strengthen seed systems, and develop value chains. Introduction of a new crop to Zambian farmers supports the crop and diet diversification strategies (Mangaba, 2017)

Key challenges for pigeonpea production in the region include being a minor crop (Phiri et al., 2024), lack of a value chain, lack of adapted high-yielding germplasm, pest management, and poor seed system. Table 1 outlines these challenges and the corresponding opportunities and responses implemented through FFSs, as identified by local farmers, stakeholders, national and international breeders, prospective business actors, and relevant NGOs. FFSs are often conceptualised as tools for improving the management of established crops, with a strong emphasis on agronomy and integrated pest management (IPM; e.g., Davis et al., 2012). Less attention has been given to adapting FFS principles for introducing a new crop with unknown agronomic risks and underdeveloped seed system and value chain. This study addresses this gap by examining an adapted FFS approach for introducing pigeonpea in Eastern Zambia and shares the methodology, challenges, and limitations encountered during implementation.

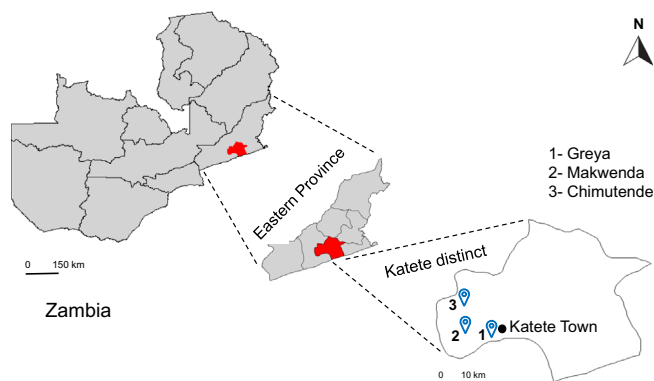
2 | FFSS IMPLEMENTATION**2.1 | Study site**

The FFSs were carried out with three communities in Katete district (Figure 1). These communities already had an established FFS programme running with Grassroots Trust (GrT) Limited in Zambia. This study focused on the pigeonpea value chain and gave rise to three new FFSs, with the goal of educating farmers on the main constraints for pigeonpea and possible solutions. The Greya community works closely with the Tikondane Community Centre (TIKO), which has long-standing ties with local farmer groups. TIKO is a community-led organization run by and for farmers in Katete.

The Katete district has a population of ~214,000 people, with the majority (87%) residing in rural areas (CSO, 2022). The Katete district has ~43,000 farming families, and about 95% of people rely on agriculture as their main source of income (Hamazakaza et al., 2022). The main crops are maize (*Zea mays*), groundnut (*Arachis hypogaea*), soybean (*Glycine max*), sunflower (*Helianthus annuus*), cowpea, mango (*Mangifera indica*), cotton (*Gossypium hirsutum*), and small gardens, which produce mixed vegetables and fruits. Livestock form an

TABLE 1 Identified challenges and opportunities of pigeonpea in the Katete district and potential farmer field school (FFS) responses.

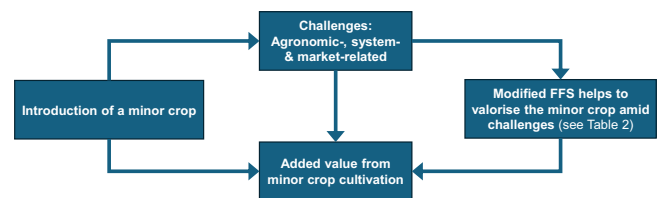
Challenges	Opportunities	Response
Lack of pigeonpea seed processing equipment in Zambia (seed dehulling)	Encourage consumption and the development of new value-added market opportunities	Support farmers with seed dehulling equipment.
Lack of seed within the farmer communities to be able to develop value chain using the pigeonpea seed dehuller	Scaling up production of pigeonpea in target area in a collaboration with farmers	Distribute pigeonpea seed to over 100 farmers in the 1st year and up to 1000 farmers in 4 years.
Limited locally adapted pigeonpea germplasm and poor seed system	To test new pigeonpea germplasm (genetic diversity)	Variety trails for farmers for selecting adapted high-yielding varieties.
Lack of knowledge in adapting pigeonpea seeds as a food ingredient	A climate-smart crop for farmers and new opportunities for the Zambian food industry	Educate farmers with the basic knowledge about pigeonpea seeds nutritional value.
No reliable commercial inoculants for pigeonpea are available in Zambia	Increasing yield stability of crop and nitrogen content of soil for following crops (plant-microbe interactions)	Pigeonpea-specific inoculants need to be developed and distributed to farmers. Additionally, there is a need for two training courses to educate farmers on benefits, applications and storage of inoculants. Leaflets providing basic knowledge about rhizobial inoculants were also provided.
Lack of knowledge on pigeonpea soil fertility and health benefits and management options	Demonstrate pigeonpea's ability to work as a green manure and cover crop in ratoon systems	Use existing FFS to involve farmers in pigeonpea's ability to improve soil fertility and health and management. (using existing GrT FFS activities)
Emerging pigeonpea insect pests	To be prepared for the future—when the cultivation of the crop is increased	Farmers members training on biological pest control.
Adoption of the FFS model has shown to be slow and difficult by farmers	To set up a suitable farm school model for the Katete district	Engaging local farmers and stakeholders, through a structured process.
Lack of knowledge of use of pigeonpea biomass for dry season livestock fodder	Demonstrate the value and best practice for the use of pigeonpea as livestock fodder	Use existing FFS/bulking-up strategies as the basis for livestock fodder training.

**FIGURE 1** Map of Zambia showing the study area of three farmer field schools (FFS) in Katete district, eastern province. Map source: <https://gadm.org/>.

important part of the rural economy, with cattle, goats, sheep, pigs, and poultry offering farmers diversified incomes and nutrition.

2.2 | FFSs design

We developed an analytical framework that articulates how core FFS principles were adapted for the introduction of a minor crop compared with conventional FFSs (Figure 2; Table 2). As pigeonpea is a

**FIGURE 2** Farmer field school (FFS) as a factor that increases the success of minor crop cultivation.

new crop in the region, a FFS set out to educate farmers on the characteristics of three commonly available pigeonpea varieties with a view to facilitating participatory variety selection by field school members (FFS1 - Variety trials; Figure 3a). The FFS1 in the variety trials consisted of three released pigeonpea varieties: Muthawajuni (ICEAP 01551, MPPV-4), ZPP14 (ICEAP 01514/15), and MPPV-2 (ICEAP 00554).

The development of sustainable solutions for pest control is crucial for establishing pigeonpea in the region. The second FFS was structured around low-cost botanical insecticide/repellents for the management of blister beetles (*Mylabris pustulata*), commonly known as the flower or CMR beetle (FFS2—Pest management; Figure 3b), which is a major pest of legumes, as it eats flowers and young pods. Two locally grown plant species, *Tephrosia vogelii* and *Solanum incanum*, were chosen as the botanical insecticides.

TABLE 2 Conceptual framework for adapting farmer field school (FFS) principles to the introduction of a minor crop (pigeonpea).

Aspect	Conventional FFS (established crops)	Modified FFS (minor crop introduction—this study)
Crop status	Often widely grown, familiar to farmers	New or marginal crop with very limited local knowledge
Primary objective	Improve management of existing practices (e.g., IPM and production)	Enable informed experimentation and risk assessment
Seed system	Functioning or semi-formal seed supply	Weak or absent seed system
Value chain	Existing markets and processing pathways	Emerging or speculative value chain
Farmer risk	Incremental (practice-level)	High (crop-level and market-level)
Learning focus	Agronomy and pest management	Crop introduction (variety trials; FFS1), potential pests and diseases (Pest management; FFS2), good agronomic practices (Rhizobial inoculants; FFS3), seed processing and market feasibility (all FFSs)
Implementation intensity	High (regular meetings, season-long)	Low-intensity, selective activities tailored to risk and resource constraints
Evaluation emphasis	Productivity and income outcomes	Process learning, feasibility assessment, and constraint identification
Critical success factor	Adoption of improved practices	Credible market and processing prospects

There was a general lack of awareness among FFS farmers regarding the benefits of using pigeonpea-specific rhizobial inoculants (GrT and farmers interviews). No commercial inoculants were available for pigeonpea in Zambia. To fill these gaps, we delivered experimental scale pigeonpea-specific rhizobium inoculants to Zambia for FFS. For this purpose, *Bradyrhizobium japonicum*, a bacterial strain CB756 (HAMBI 1341, University of Helsinki, Finland) was used. The inoculants were produced in Finland (Elomestari Oy, Tornio), using the trap host technique and nodulation was tested in a pot experiment at the greenhouse at the University of Helsinki. After official import permits were obtained from the Zambian Ministry of Agriculture, the inoculants in peat carriers were transferred to Zambia. The major challenge was the risk for poor handling, storage, or transportation of inoculants by farmers, which could reduce their viability and effectiveness. To address this concern, FFS members were trained (FFS3—Rhizobial inoculants; Figure 3c) with the following learning objectives: (a) introduction to rhizobial inoculation; (b) hands-on training in the effective use of inoculants in the field; (c) understanding the

correct methods for applying inoculants to seeds; and (d) hands-on training in the proper handling and storage of inoculants. The rhizobial inoculants were delivered to lead farmers at all three FFS sites (2023 and 2024). All FFSs were designed with three replicates and control treatments.

2.3 | Data collection

There were 76 participants in 2023 and 111 in 2024 (Table 3). We did not place any emphasis on age or gender, and the FFSs were open to everyone. Participant numbers were recorded and disaggregated by gender; however, the study did not collect sex-disaggregated outcome data, and no formal gender analysis was conducted.

In 2024, protocols were simplified, and groups selected new host farmers. Each group designated a focal-point farmer responsible for coordination and communication. Communities were asked if they had other issues that needed to be added to the FFS curriculum for pigeonpea, but because this is a new crop, communities focused on learning on these three key points.

During initial meetings, communities selected host farmers responsible for managing the field schools, who were then trained and provided with field guides, seed, and required inputs. Farmers were given the contact details of the facilitator and encouraged to communicate any challenges for quick resolution. Partner organisations, GrT, TIKO, and Zambia Ministry of Agriculture had committed to assisting farmers in the implementation of the pigeonpea FFSs.

Evaluation relied on group participation in planting and field visits. Unlike conventional FFSs, the approach did not require regimented weekly meetings. This methodology is a response to well-documented feedback on FFS over the years, where farmers report that the traditional field school approach took too much time from their already busy work schedule, and this presented a significant opportunity cost (Manoj & Vijayaragavan, 2015; Waddington et al., 2014). Like current FFSs, the facilitator visited each FFS four times per season (pre-season, vegetative stage, reproductive stage, and post-harvest). During visits, demonstration fields were inspected, informal discussions held with farmers, and qualitative observations on crop performance and management challenges recorded for analysis. These visits involved informal interviews, where the facilitator observed basic agronomic conditions and cultivation challenges, engaged with farmers based on these observations, and offered relevant advice. All observations were documented and qualitatively analysed from both advisory and agronomic perspectives. Additionally, unlike other FFS approaches, this programme focuses on multi-year crop cycles rather than single cycles, as these consider differences in climate and markets across seasons. This approach is also important with respect to observing long-term changes in soil fertility and crop performance, a key area of intervention for GrT. Additional meetings were organised by group members as needed, for example in response to drought or pest outbreaks.

In addition to the FFS methodology described above, that emphasised the delivery of agronomic information to farmers, they were

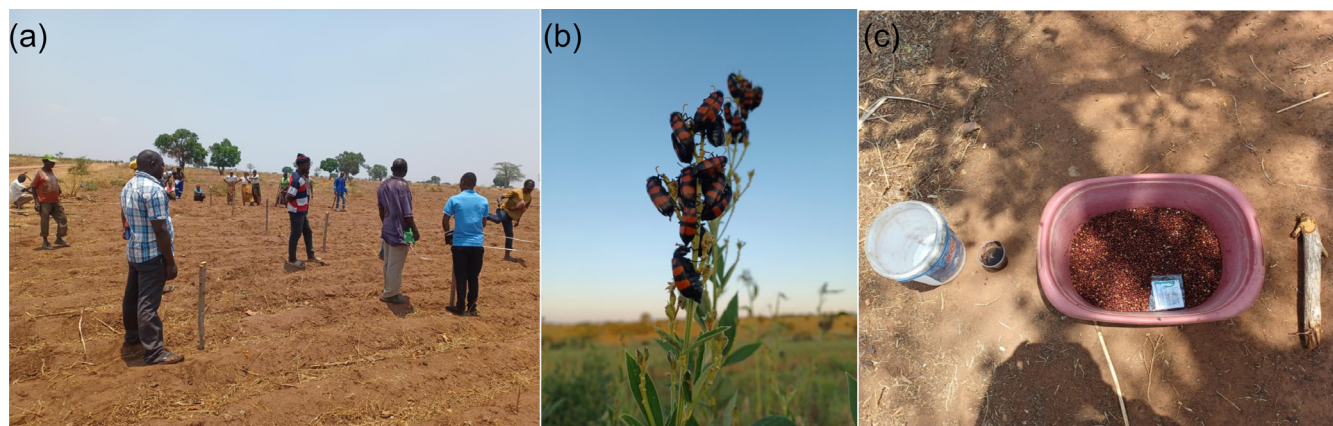


FIGURE 3 Farmers planning the FFS1 pigeonpea variety trials (a). Blister beetles feeding on pigeonpea flowers (FFS2) (b). Training session for farmers on the application of rhizobial inoculation of pigeonpea seeds under FFS3 (c). FFS, farmer field school. Photo credits: Hamid Khazaei.

TABLE 3 Farmer field school (FFS) participants information for years 2023 and 2024.

FFS	2023		2024	
	Female	Male	Female	Male
Chimutende	10	15	12	12
Makwenda	10	21	13	8
Greya	11	9	40	26
Total	76		111	

given small amounts of seed to use for the purpose of individual experimentation to gain experience with this new crop. This approach was also a means of ‘bulking up’ pigeonpea seed grain to begin developing a local value chain around pigeonpea processing/dehulling. Over the first two cropping seasons, farmers received pigeonpea seeds under this part of the programme. The amount of seed given to farmers in the 2024/25 season was equivalent to approximately 12 ha (on average 0.11 ha per farmer) of pigeonpea if grown as a pure stand, using a seed rate of 7 kg per ha.

Postseason meetings with farmers were established to discuss key constraints and opportunities for the future of pigeonpea in Katete district.

3 | OUTCOME

During the first year of establishing FFSs (2023/24) Zambia faced a severe drought emergency that resulted in widespread crop failure (FAO, 2024), including the collapse of our pigeonpea FFSs and seed bulking in the Katete district. Most farmers failed to establish pigeonpea successfully in 2023/2024, and crops that emerged were lost to severe drought.

In 2024/2025, erratic rainfall at the beginning of the season also led to the lateness of planting for FFSs and for scaling fields. This phenomenon was exemplified by the fact that these farming communities

had 2 years of failed crops (drought 2023/2024 and soybean rust disease 2022/2023), so they were, understandably, focusing on planting crops they knew that had a secure market for, that is, maize, soybean, sunflower, and groundnut. Farmers reported repeated replanting due to poor germination across multiple crops. This is particularly relevant to pigeonpea, as early planting is essential to reduce the risk of damage from free-grazing livestock. In the second year, across the three participating sites 22% successfully established a pigeonpea crop during the learning/bulking-up phase (Table S1).

The participation of farmer groups has several dynamics, depending on each community in the second year of running FFSs. Reasons provided during FFS meetings and discussions with group members indicated that farmers' reluctance to invest time and resources in pigeonpea cultivation was primarily driven by three factors: (a) the absence of a reliable market and price structure compared with conventional staple crops such as maize, (b) two consecutive failed agricultural seasons, which led to reduced ability to absorb the risk of growing a new crop, and (c) the emergence of gold mining opportunities in Makwenda and Chimutende, which offered more immediate economic returns than agriculture. In Greya, participation has improved, which could be attributed to TIKO having a long-standing relationship with local farmer groups. A contributing factor here was that TIKO agreed to host the pigeonpea dehuller and facilitate market linkages, a message that encouraged the farmers in the TIKO area to take part in the FFS and bulking-up programme. Farmer commitment varied with perceived market opportunities: farmers in Greya, where credible market opportunities existed, showed higher engagement in seed bulking and crop management, while participation was lower at sites further away from TIKO.

3.1 | FFS observations

3.1.1 | FFS1

Two pigeonpea varieties were shown to be early-medium (Muthawajuni and ZPP14) and one being late medium maturity

MPPV-2. Early-medium maturity varieties flowered and set seed earlier than the later-maturing MPPV-2, which also had higher plant height.

3.1.2 | FFS2

Pest management activities were not implemented, as poor crop establishment due to erratic rainfall led farmers to consider field-level application unnecessary. As a result, learning related to botanical pest control remained at the level of training and discussion rather than hands-on practice.

3.1.3 | FFS3

Training on the handling and use of rhizobial inoculants was delivered to farmers, and inoculants were applied in a limited number of fields where crop establishment was successful. To assess inoculant effectiveness, selected plants were uprooted and roots examined for nodulation. Pigeonpea in Greya showed substantial active nodules (Figure S1).

Postseason meetings with farmers revealed and reinforced several key points made by the farmers about the serious challenge posed by free-grazing livestock. Placement of the fields away from livestock corridors to communal grazing areas, experimenting with spraying the pigeonpea plants with a mixture of cattle and goat manure and urine as a deterrent for livestock, early planting and selection of earlier maturity varieties were significant contributions by the farmer groups. Farmers also commented on several possible interventions with regards to CMR beetles. Use of the beetles themselves, hand-picked, soaked in water and sprayed onto the flowers of the pigeonpea plants. Others cited several commonly available registered pesticides for the control of the beetle, citing effective control when sprayed twice or three times during flowering.

4 | DISCUSSION

Despite the challenges we encountered during the implementation of FFSs, this initiative represents the first successful design and testing of pigeonpea-specific inoculants for Zambia. Our FFSs targeted a minor crop with a poor seed system, undeveloped value chain, and crop-specific risks such as drought, late maturity, and livestock grazing pressure. Farmers were trained in good agronomic practices, informed about the importance of biological control, and provided access to pigeonpea varieties adapted to their farming systems. Additionally, a pigeonpea seed dehuller was imported to the country for the first time to support the development of the value chain.

While traditional FFS models mainly focus on agronomy and IPM, we went beyond production and explicitly integrated seed processing development for pigeonpea. This may have a significant impact on the crop value chain, as seed dehulling is a critical step in generating value

from the crop. Similar value chain oriented FFS initiatives have been reported in Zambia for common bean with different seed processing requirements. For example, FFSs around the common bean value chain, where farmers reported increased yields and higher profits from bean sales after adopting the improved practices introduced through the FFS (World Vision, 2021).

Overall, we had more women participating in FFSs than men in 2024. Women's participation in the FFSs does not necessarily lead to equal benefits or decision-making power. Constraints related to labour, land access, and markets are well documented in FFSs and legume systems (e.g., Davis et al., 2012). These aspects were not assessed in this study and need future attention.

Implementation of the FFSs was constrained by several challenges listed below:

- Erratic rainfall distribution and extreme weather conditions

The climatic conditions were the primary factor that hindered the performance of the FFSs during the first and second years. These adverse conditions had a significant impact on the establishment of the pigeonpea crop, which is a particularly critical stage for its growth and development. Poor crop establishment during this period can lead to crop failure. Pigeonpea is drought adapted once the plants are established. It can grow across a six-month dry season (Cook et al., 2005; Odeny, 2007).

- Lack of a value chain

Most farmers doubted that there was a market for pigeonpea in the region. Zambia has found a ready market for pigeonpea in India and wants farmers to capitalise on the opportunity. To date, despite having a small (about 100 t/year) local market for processed pigeonpea, Zambia does not have any seed processing equipment for pigeonpea. As a result, all the processed pigeonpea dahl consumed in Zambia is imported. To support the development of the pigeonpea value chain, the Z4ABC project (Zambia for Agroforestry, Biodiversity and Climate) funded the importation of a dehulling machine from India to Zambia in early 2025. As a result, farmers in Katete now have access to a dehuller. This was perceived as an important improvement in the value chain. Local marketing in Katete and nearby Chipata, followed by the bigger markets in Lusaka and Copperbelt, are the core focus of the value chain.

- Lack of developed seed systems for pigeonpea

Zambia Agricultural Research Institute (ZARI) is leading a pigeonpea pre-breeding programme in Chipata, which is in its early stages. The programme awaits germplasm from ICRISAT to begin making initial crosses and launching a formal breeding programme. The Catholic Relief Services has been actively involved in the distribution of pigeonpea seeds to farmers over the last decade, sourcing seeds from ZamSeed and ICRISAT. Most of the seeds originated via Malawi from ICRISAT Kenya. Most of those varieties are mid-to-late maturing

varieties, e.g., MPPV-2. The later-maturing varieties tend to be eaten by free-ranging livestock in the field after the month of June. Several pigeonpea germplasm have been developed for Eastern and Southern Africa, many of which are potentially adaptable to Zambia (Kaoneka et al., 2016). The potential of selecting suitable lines to improve the dehulling efficiency and market acceptability and pricing is also of interest. Currently, the majority of the pigeonpea germplasms available in Zambia are vegetable types, which typically have relatively large seeds, relatively low dehulling efficiency and relatively low market prices in India.

- Pigeonpea at risk from free-grazing livestock

Farmers were concerned about the survival of pigeonpea in their fields from month May onwards, as this is when livestock owners stop herding their free-range goats and cattle. Since pigeonpea matures around this time, the crop becomes highly vulnerable to grazing. Fencing their fields is not a viable solution because of labor, financial, and traditional land ownership structure constraints. To mitigate the risk of livestock damage, some farmers plan to plant pigeonpea in their home gardens, where they can better protect it from destruction. Farmers also requested that the programme make efforts to identify slightly earlier maturing varieties, which would reduce the window or pressure from free-ranging livestock. We have identified early-maturing varieties and locally adapted deterrents as potential strategies measure to reduce losses from livestock.

- Strengthening farmer engagement through communication

During the establishment phase, a multiactor platform was convened to engage relevant stakeholders. District agricultural staff, community representatives, and implementing partners (TIKO and GrT) participated in a pre-season meeting in 2023, where the programme was introduced and stakeholder expectations were discussed. Participants agreed that institutional oversight would strengthen support for FFSs on pigeonpea; however, farmers subsequently reported limited follow-up, mainly due to staffing constraints.

Without support during the establishment of the FFS learning sites, effective communication by the FFS host farmer or responsible community member is essential for the FFS approach used. The current approach, where the facilitator meets FFS members 4 days in a year versus 20 or 30 days used in other FFS methodologies, offers the potential to reduce barriers to entry into the implementation of FFS (Waddington et al., 2014). It lowers the costs of FFS but also leaves more responsibility to the local FFS lead farmers, especially for more complicated FFS learning sites, such as the randomised, replicated approach used here. Relying on groups to communicate with the absent facilitator proved ineffective in all but one case in Greya, where communication from one field school host was good and the field school was established successfully and to a good standard. Where resources allow, regular field observations

remain important for maintaining FFS quality. Design, field support, and monitoring and evaluation are key quality indicators that must be upheld in FFS implementation (van den Berg, Phillips, et al., 2021). FFSs are not intended to replace existing agriculture extension systems. However, certain FFS principles can be selectively incorporated into various systems, such as agricultural extension (Anandajayasekaram et al., 2007). In our experience, monitoring and evaluation by local NGOs or government extension staff could have enhanced the success of the FFSs.

Unlike conventional FFSs targeting established crops, pigeonpea faces limited familiarity, undeveloped seed systems, and an underdeveloped value chain in the region. Farmer participation was strongly influenced by perceived processing and market opportunities. The low-intensity facilitation model used here addresses long-standing critiques regarding time demands and scalability (Waddington et al., 2014), and illustrates how FFS principles can be selectively adapted to high-risk, resource-limited contexts rather than applied as a universal model.

Using the described FFS methodology, several lessons were learned for future FFS and related participatory approaches, where emphasis is placed on farmer-led establishment and management of FFS sites, and much of the learning depends on the field itself. In this particular case, where the aim was to introduce a new crop, farmer buy-in depended heavily on their confidence in the availability of a reliable market for the end product, pigeonpea dahl. This was demonstrated by the Greya, which had the most participation in 2024 and also seed bulking-up activity compared with the other communities. Despite being aware that the dehuller had not yet arrived, their strong affiliation with TIKO gave them a closer connection to the potential market and greater confidence in the eventual sale of pigeonpea dahl. The dynamics surrounding farmers' buy-in through interest and participation in FFS are diverse and varied (Bakker et al., 2020; van den Berg et al., 2020). The FFS approach requires efficient and timely communication between facilitators and farmer groups to be effective. Therefore, our case study suggests that effective communication and careful observation of the FFS are critical to ensuring it achieves the desired outcomes.

Collaboration with partner organisations could help with the effective establishment of FFS sites, but only if these organisations have the capacity to oversee field operations to the standard needed. The drawback of relying on partner organisations for support is that the FFS hosts invariably wait for extension officers to arrive rather than planting the crop themselves. Late plant establishment is particularly important for pigeonpea, as it needs to be planted early in the season so that the maturity of the crop does not coincide with that of free-ranging livestock.

5 | CONCLUSIONS

This study highlights the challenges, limitations, and adaptations of FFS when applied to a crop with limited familiarity, an undeveloped

seed system, and an emerging value chain, using pigeonpea as a case study. The modified FFS approach explored here integrated agroeconomic learning with early-stage value chain considerations and responded to long-standing concerns regarding the time demands of conventional FFS models. Through the FFSs, farmers strengthened their knowledge of good agronomic practices, biological pest control, and the use of adapted varieties, and gained access to a seed dehuller. The approach has the potential to contribute to crop diversification, soil fertility improvement, sustainable agriculture, and enhanced rural livelihoods, particularly if supported by continued investment in value chain development, seed system, and climate-resilient implementation.

AUTHOR CONTRIBUTIONS

Hamid Khazaei and Sebastian Scott wrote the original draft. Hamid Khazaei, Sebastian Scott, and Jarkko K. Niemi reviewed and edited the manuscript. All the authors read and agreed with the published version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

The datasets developed during the current study are available from the corresponding author upon request. Requests regarding the rhizobial inoculants should be directed to the corresponding author.

ETHICS STATEMENT

Ethics approval was not required for the present study. All farmers participated voluntarily in the FFSs, and they had to indicate their consent to participate in the pigeonpea activities. Before joining the FFSs, the purpose of the pilot was explained to the farmers, and they had the possibility to ask questions before deciding whether to

participate in the pilot. The farmers had the option to discontinue in the pilot at any time without having to explain the reason.

ORCID

Hamid Khazaei  <https://orcid.org/0000-0002-5202-8764>

Sebastian Scott  <https://orcid.org/0009-0006-9073-9520>

Jarkko K. Niemi  <https://orcid.org/0000-0002-9545-3509>

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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